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NRL TRANSMITTANCE MEASUREMENTS AT DIRT-III.(U)
JUN 81 J A CURCIO, K M HAUGHT, M A WOYTKO
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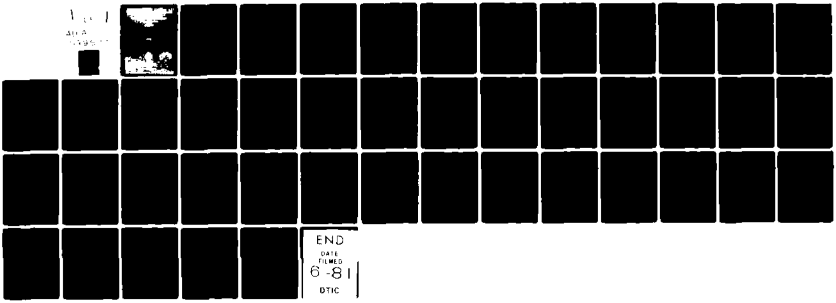

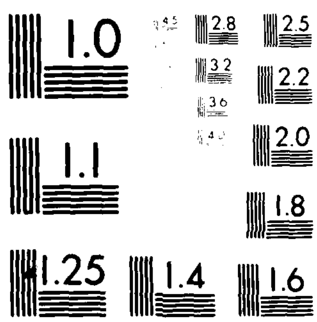

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This is a final report on NRL experiments at the DIRT-III tests at Fort Polk, Louisiana in April, May 1980. Spectral transmission data at 3 wavelengths, 0.55 μm, 1.06 μm and 10.4 μm is reported for 27 events in natural soil and various prepared soils. Spectral transmittance of smoke and dust clouds generated by explosive charges was found to be independent of wavelengths in about 50% of the events where useful data was obtained. When the charge was buried in wet natural soil transmittance at 10.4 μm was < transmittance at 0.55 μm.

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CONTENTS

NRL TRANSMITTANCE MEASUREMENTS AT DIRT-III

INTRODUCTION

This is a final report on NRL experiments at the DIRT III tests at Fort Polk, Louisiana, in April-May 1980. The NRL experiment was designed to measure spectral transmittance through smoke and dust clouds generated by static detonations of various explosive charges in natural soils and prepared soils. Spectral transmission data as a function of time was obtained for 82 events. Because of unfavorable wind conditions, many data runs of short duration ($\leq$ 5 secs) are not included in this report.

INSTRUMENTATION

The transmissometer used in the DIRT III tests consisted of a source, receiver and associated recording and data processing equipment. A 600 watt halogen filled narrow filament tungsten lamp in a 24" diameter searchlight served as the source having a beam width of 20 mr. Filament emission provided energy at 0.55 μm and 1.06 μm while the quartz envelop at 1000^{o} C provided energy at 10.4 μm. Radiations were modulated at 750 Hz by a mechanically driven slotted chopper cage.

The receiver assembly consisted of a two-detector section for 0.55 μm and 1.06 μm and a coaxial section for 10.4 μm. The two-detector section consisted of 2 Si detectors, filters and beam splitter; each detector had a FOV of 0.6 mr, equivalent to a field of about 52 cm diameter in test area. A HgCdTe detector at the focus of a 60 cm diameter, f/2.3 mirror detected 10.4 μm radiation. The filter spectral half bandwidth were: 0.55 μm - 8 nm, 1.06 μm - 0.01 μm and 10.4 μm - 0.15 μm. Leg supports resting on the ground decoupled the receiver assembly from all trailer motion.

The transmitter source was located at the N.E. end of the optical path, 0.87 km from the receiver. All detonations took place in a 100 x 200 m area midway between receiver and transmitter sites. Data were obtained as the dust and smoke clouds moved through the optical beam about 5 m above ground.

The recording equipment was started at -3 min to establish 100% and 0% transmission signal levels. This procedure removes atmospheric path effects so that measured transmission losses are caused by smoke and dust clouds in the path. Turnoff after the event occurred when the 100% level was re-established, for most events at about +2 minutes. The data were sampled and processed in real time once each second, printed on paper tape, stored in the calculator memory and recorded on magnetic tape. Graphs of transmittance data which were prepared later in the laboratory are included in this report as Figs. 1-32. We estimate the accuracy of the transmittance measurements to be about $\pm$ 5%.

Manuscript submitted March 18, 1981.

TEST COMMENTS

The test program consisted of two series of events. In the first series various charges were detonated on the surface or buried in natural soils at various positions in the test area. Prepared soils of various compositions such as sand, clay and silt were used in the second series. Test comments on various natural soil events are given in Table I and prepared soils in Table II.

VISIBILITY MEASUREMENTS

Visibility was determined by the contrast method developed by Koschmieder where visibility is defined as the distance from an object that produces a threshhold contrast between the object and the background. In these experiments the target was the interior of a darkened van 0.87 km away, and the background was the sky immediately above the van.

The contrast formula is

$$\frac{B_H - B_X}{B_H} = e^{-\alpha X} = T_X \text{ (contrast transmittance)},$$

where B_X and B_H are the radiances of the cone of air in front of the target at distance X and the horizon, respectively. Attenuation coefficient α in the visible region can generally be attributed to aerosol scattering. However in high visibility conditions the molecular component is a significant factor and must be considered in determinations of aerosol effects.

For visibility determination we define γ as the threshhold contrast where the target is minimally visible and R is the range at that contrast. For our work we let $\gamma = 0.02$ at a wavelength of 0.55 μm, so that

$$\frac{B_H - B_R}{B_H} = e^{-\ R} = 0.02,$$

or visibility = $3.92/\alpha$. An optical pyrometer is a convenient instrument to use for the determination of B_R and B_H. With a programmable hand calculator, a visibility determination can be made in about 1 minute. Table III summarizes visibility measurements made during DIRT III.

TRANSMITTANCE RESULTS AND DISCUSSION

Most of the data was obtained when various charges were detonated on the surface or buried in dry dusty natural or prepared test soils. Tests during the period April 17th - April 22nd were made on the surface or buried in wet natural soils following a heavy rain shower on April 17th. The data shown in Figs. 1-27 have been examined for possible correlation of spectral transmittance with soil type or soil moisture content. To do this transmittance at 10.4 μm was selected as reference and relative transmittances at 1.06 μm and 0.55 μm were noted for each event. This analysis is shown in Table IV, which has a tabular listing of events where transmittance at 10.4 μm was > 1.06 μm or 0.55 μm, < 1.06 μm or 0.55 μm, generally equal to 1.06 μm or 0.55 and a fourth column where 10.4 μm transmittance was initially less and gradually became greater than 1.06 μm or 0.55 as the cloud developed and passed through the optical beam.

In the grouping (Col. A) where 10.4 μm transmission > 1.06 μm or 0.55 μm, the events were all surface firings during dry soil conditions. Fig. 25, (event TS-34, dry prepared kaolin on sand and clay) and Fig. 26 (TS-38, moist prepared sand) show greater transmittance in the non-opaque region and are included in this group.

In the grouping (Col. B) where the spectral attenuation is non-selective i.e., transmittances are equal at the 3 wavelengths, we find most of the prepared soil tests which yielded useful data and 4 surface shots on natural dry soil. The preponderance of prepared soil events in this grouping does not appear to correlate with soil type or soil moisture content. It is probable that texture of the prepared soil is an important factor in determining particle characteristics and spectral transmittance properties of the smoke and dust cloud.

The grouping (Col. C) contains events where IR transmittance at 10.4 μm was less than transmittance at 1.06 μm or 0.55 μm. These events occurred during the period 4/17/80 - 4/19/80 when the natural soil in the test area remained wet after a heavy rainfall on 4/17. In addition, the charges were buried which gave rise to a large concentration of wet soil in the smoke and dust cloud. Since the 10.4 μm spectral band is in a region of strong liquid water absorption, it is likely that the decreased transmittance at 10.4 μm can be traced to a small amount of bulk liquid water from the wet soil which has been carried into the cloud by the soil particles.

Column D is an interesting category of 4 events, 3 buried and 1 surface, where the transmittance at 10.4 μm is less than transmittance at 1.06 μm or 0.55 μm during early time of an event and becomes greater during latter stages of cloud growth. All these events occurred during the period 4/18 - 4/22 after the heavy rain. Figure 16 (event E-6) is a good example of this reversal of transmittance ratio. The transmittance curves are unusual in that the early time data, when the cloud sample in the optical beam had a high content of wet soil, 10.4 μm transmittance is less than 0.55 μm. Beyond about +45 secs, when the cloud sample in the beam is mostly smoke and fine soil particles, the IR transmittance at 10.4 μm is > visible transmittance at 0.55 μm. This behavior is also shown in Fig. 5, Fig. 10 and Fig. 15.

RAIN AND VEHICULAR DUST

Figure 28 shows spectral transmittance data for a 6 min period at the beginning of a rain shower on 4/17/80. Lower transmittance at 10.4 μm is similar to DIRT tests in wet soil as shown in Fig. 1, event 4. Here also the lower transmittance in rain is probably caused by small amounts of liquid water in the optical path. Lower transmittance at 1.06 μm relative to 0.55 μm is somewhat puzzling but may be a scattering effect from the rain particle size distribution. This data run was interrupted by light source failure at +7 min and resumed after a break of about 30 min for repairs.

Figure 29 is a continuation of the rain data from 1938 to 2040 GMT which includes an intense shower period of 5 min at 2025 GMT or +1620 secs on Fig 29. Transmittance at 10.4 μm is greater than 0.55 μm before the intense shower and less than 0.55 μm during and after the shower. High time resolution of transmittances during the intense shower period is shown in Fig. 30.

Figures 31 and 32 show transmittances of vehicular dust in the optical path for two short periods on 4/21. Data shown in Fig. 31 indicates a light dust where 0.55 μm has higher transmittance than 1.06 μm or 10.4 μm. In Fig. 33, transmittances which varied from 30% to 100% are equal at all three wavelengths.

CONCLUSIONS

The data has been summarized in Table IV from which the following conclusions have been made:

1. Spectral transmittance of smoke and dust clouds generated by explosive charges was independent of wavelength in about 50% of the events where useful data was obtained. Most (82%) of the useful events in prepared soils were in this category which suggests a high concentration of large size soil particles independent of soil type in the prepared soils.

2. Data from natural soil events was almost equally grouped in events where transmittance at 10.4 μm was < , = or > transmittance at 0.55 μm. Spectral transmittance at 10.4 μm through clouds from surface events on dry natural soils was > or = transmittance at 0.55 μm.

3. When the charge was buried in wet natural soil transmittance at 10.4 μm was < transmittance at 0.55 μm. In about 50% of the buried wet soil events, transmittances at 10.4 μm was < 0.55 μm during the early time cloud and > in the later stages of the cloud when the larger soil particles had dropped out.

4. Useful spectral transmission data was obtained in 27 of a total of 82 events. This low percentage caused mostly by unpredictable wind conditions has resulted in an unbalanced data set. For example little useful data was obtained from events buried in natural soil or similarly from surface events on wet soil.

5. The spectral transmittances of smoke and dust clouds in this report were obtained with a detector system having a FOV of 0.6 mr and sampled a small and variable cloud test volume whose cross-section was about 0.2 m^2. An optical system with a larger FOV would accept more scattered radiation and show higher transmittance values. Because cloud growth rate, wind conditions etc, measurements made through some other spatial section of the cloud would give a different data profile. This suggests that when transmittance data is required for a practical application the optical parameters in the test procedures should be similar to those in the device.

RECOMMENDATIONS

1. Since tests with prepared soils of various compositions resulted in similar spectral transmittances, their usefulness in spectral transmission tests is questionable. This problem should be examined.

2. Spectral transmittance measurements through vehicular dusts should be an essential part of future DIRT tests. When weather permits, transmittance tests in rain and fog should be carried out on a summary schedule basis.

3. Broad spectral bandpass regions such as 3-5 μm and 8-12 μm which have military application should be investigated.

4. In a future DIRT test there should be events designed to study effects of parameters such as soil moisture and detector field of view on spectral transmittance.

ACKNOWLEDGMENT

Many thanks are due Mrs. Barbara Eckert for her dedicated and careful typing of this manuscript.

TABLE I

DIRT TEST III A - COMMENTS

A1 - Optical alignment disturbed by shock wave - poor data.
A2 - 7 kt wind, 5 secs of data, poor run.
A3 - Fire on 3rd try, 25 secs of data.
A4 - Prior to heavy rain shower, 90 secs of good data.
A5 - Wet soil 25 secs data, thin cloud, IR < visible or 1.06 μm.
A6 - Wet soil, 25 secs data, IR transmission < visible or 1.06 μm.
A7 - On C1, light wind, 60 secs good data IR < visible or 1.06 μm.
A8 - Wet soil, quick pass, unusual spectral transmission at +6 secs.
A9 - Cloud did not pass thru beam, no data.

B1 - On optical axis, good shot, 90 secs of data IR > visible or 1.06 μm.
B2 - Fired on 3rd try, 35 secs of good data.
B3 - Light cloud through beam, about 30 secs of data.
B4 - 15 secs of data - IR shows lower transmission in dense cloud.
B5 - Thin cloud, data for about 60 secs.
B6 - No data.
B7 - Cloud did not cross beam, no data.
B8 - Quick blow across path, no data.
B9 - Quick pass through beam, poor data.

C1 - Quick pass, poor data.
C2 - 20 secs of good data.
C3 - 10 secs of data through dense cloud, all wavelengths extinguished.
C4 - 55 secs of data, IR shows lower transmission in dense cloud.
C5 - Wet soil, 15 secs of data, IR has lower transmission in dense cloud.
C6 - Dry conditions, cloud remnants lingered for 3 minutes.
C7 - Wet soil, quick pass, few data.
C8 - 15 secs of surface dust data, weak attenuation.
C9 - 25 secs of data, weak attenuation is non-selective spectrally.

D1 - Quick pass, 10 secs data.
D2 - Cloud lingered in path, 90 secs of good data.
D3 - Thin patchy smoke, 15 secs of irregular data.
D4 - Wet soil, quick pass, 1.06 μm channel erratic poor data.
D5 - Wet soil, quick pass, 5 secs data, poor.
D6 - Wet soil, quick pass, 10 secs data, IR < vis or 1.06 μm in dense cloud.
D7 - Very light smoke across beam, weak attenuation.
D8 - 6 secs of dense cloud data, thin cloud lingered for 50 secs.
D9 - 30 secs of data, IR transmission lower in dense cloud.

E1 - 5 secs dense cloud data, 40 secs good data.
E2 - Dense cloud moved into beam for 8 secs, 25 secs good data.
E3 - Cloud moved across beam, opaque 5 secs, 40 secs of good data.
E4 - Quick pass dense cloud, thin cloud remained for 20 secs, IR attenuation > visible or 1.06 μm in dense cloud.
E5 - Low turbulence, low wind, good shot 2 minutes of data.
E6 - Good data of a thin cloud, about 2 minutes.
E7 - About 30 secs of data, quick pass of dense cloud.
E8 - 110 secs of good data, IR attenuation > visible or 1.06 μm in dense cloud.

TABLE II

DIRT TEST III B - COMMENTS

TS-1 - Cloud above beam - no data.
TS-2 - About 20 secs of data - wind 5-10 kts.
TS-3 - Wind picked up 7 kts, 25 secs data.
TS-4 - Light wind on CL, light cloud, 8 secs data.
TS-5 - Calm, cloud did not enter beam, no data.
TS-6 - On Cl, calm, 35 secs data - good shot.
TS-7 - Quick move out, not much data.
TS-8 - Quick move out 4 secs data - poor.
TS-9 - 15 secs of data strong winds in test area.
TS-10- About 5 secs of data - strong winds in test area.
TS-11- 7 kt wind, thin cloud, 50 secs data, lower part of cloud moved across beam.
TS-12- On Cl, quick move out of beam, 60 secs residual.
TS-13- Light wind, light cloud, 15 secs data.
TS-14- On Cl, calm, 15 secs data, fair.
TS-15- Strong winds, fast move across, about 20 secs data,
TS-16- 10 secs data.
TS-17- Quick blow, 4 secs data - nothing.
TS-18- 6 secs data poor.
TS-19- About 60 secs data, irregular, neutral, good.
TS-20- On Cl - 50 secs data - fair.
TS-21- 40 secs data, cloud did not extinguish light.
TS-22- 4 secs data - poor.
TS-23- No cloud, some attenuation on Vis & IR, source unknown.
TS-24- Calm, hole in cloud, IR slow in reestablishing 100% - good data.
TS-25- Cloud went wrong way - no data.
TS-26- Quick pass, 6 secs data, fair.
TS-27- Good data, 60 secs 4 kt wind, slow drift.
TS-28- Quick pass, 2 secs.
TS-29- Cloud went wrong way - no data.
TS-30- 3 secs data - not much.
TS-31- Data of lower cloud, main cloud drifted above beam.
TS-32- Quick pass - cloud blown away from beam.
TS-33- No cloud in beam, ground cloud drifted in, good shot of low stuff.
TS-34- 25 secs good data - calm winds, IR > vis of 1.06 μm.
TS-35- 10 sec data, 7 kt wind.
TS-36- Quick blow, 2 secs. no data.
TS-37- 7 secs of fair data - cloud drifted across beam.
TS-38- Quick pass of main cloud, low cloud drifted in for 35 secs.
TS-39- 5 secs data - poor.
TS-40- No run.
TS-41- No run.
TS-42- 20 secs data, fair run.
TS-43- 6 secs data - fair IR > vis or 1.06 μm.
TS-44- 4 secs - poor data, fast pass.
TS-45- Repeat dry silt, hole in cloud, IR Vis did not reestablish 100% haze on detector.
TS-46- On Cl, 5 secs data, no tabular data.

TABLE III

CONTRAST VISIBILITY MEASUREMENTS AT DIRT III

Date	Time	(Visibility (km)	Contrast $(1 - B_X/B_H)$*	Comments
4-9-80	1045	48	.93	
4-9-80	1210	68	.95	
4-10-80	0900	40	.92	
4-10-80	1300	40	.92	Smoke on Horizon
4-10-80	1515	31	.89	Smoke on Horizon
4-10-80	1540	30	.89	Smoke on Horizon
4-11-80	0935	19	.83	
4-11-80	1330	36	.90	
4-12-80	0820	31	.89	
4-12-80	0955	43	.92	
4-12-80	1030	109	.96	
4-14-80	0810	60	.94	
4-14-80	0905	68	.95	
4-14-80	1105	77	.95	
4-14-80	1125	59	.94	
4-14-80	1210	63	.95	
4-14-80	1330	62	.94	
4-14-80	1415	41	.92	Clouds on Horizon
4-14-80	1425	42	.93	
4-14-80	1510	109	.96	
4-14-80	1630	39	.91	
4-15-80	0830	84	.96	
4-15-80	1110	87	.96	
4-15-80	1200	63	.95	
4-15-80	1346	61	.95	
4-15-80	1450	47	.93	
4-15-80	1540	54	.94	
4-15-80	1635	42	.93	
4-16-80	1100	35	.91	
4-16-80	1320	25	.87	
4-16-80	1417	23	.85	
4-16-80	1505	29	.89	
4-16-80	1555	59	.94	Clouds on Horizon
4-16-80	1633	61	.95	Clouds on Horizon
4-16-80	1710	32	.90	Clouds on Horizon
4-17-80	1145	39	.92	50% Overcast
4-17-80	1355	27	.88	Begin Rain
4-17-80	1405	4.3	.45	Heavy Rain
4-17-80	1445	13	.77	
4-18-80	0840	57	.94	Clouds on Horizon
4-18-80	1004	52	.94	Clouds on Horizon
4-18-80	1105	30	.89	100% Overcast
4-18-80	1155	32	.90	100% Overcast
4-18-80	1325	51	.94	100% Overcast
4-18-80	1405	61	.95	100% Overcast
4-18-80	1445	46	.93	100% Overcast

TABLE III (Continued)

CONTRAST VISIBILITY MEASUREMENTS AT DIRT III

Date	Time	(Visibility (km)	Contrast $(1 - B_X/B_H)$*	Comments
4-19-80	1020	37	.91	
4-19-80	1204	29	.89	
4-19-80	1315	26	.88	
4-19-80	1430	36	.91	
4-19-80	1500	38	.91	
4-21-80	1220	33	.90	
4-21-80	1340	33	.90	
4-21-80	1505	25	.87	
4-21-80	1645	30	.89	
4-21-80	1700	16	.81	Dust in Path
4-22-80	1020	34	.90	
4-22-80	1200	25	.87	
4-22-80	1400	19	.83	Dust in Path
4-22-80	1605	37	.91	
4-23-80	0910	33	.90	
4-23-80	1005	26	.88	
4-28-80	0920	32	.90	Cloudless Sky
4-28-80	0955	36	.91	Cloudless Sky
4-28-80	1120	30	.89	Cloudless Sky
4-28-80	1605	31	.90	Cloudless Sky
4-29-80	0710	18	.82	
4-29-80	0730	24	.87	
4-29-80	0800	41	.92	
4-29-80	0830	47	.93	
4-29-80	0920	49	.93	
4-29-80	1210	27	.88	
4-29-80	1345	50	.93	
4-30-80	0645	5.4	.53	Hazy
4-30-80	0730	5.0	.50	Hazy
4-30-80	0800	6.0	.56	Hazy
4-30-80	0830	9.0	.70	Clearing Haze
4-30-80	0859	17	.82	
4-30-80	0920	20	.84	
4-30-80	0950	20	.84	
4-30-80	1115	28	.89	
4-30-80	1230	18	.83	
4-30-80	1340	24	.87	
5-1-80	0700	12	.75	Slight Haze
5-1-80	0750	22	.86	
5-1-80	0920	28	.88	
5-1-80	1025	24	.87	
5-1-80	1220	21	.85	
5-1-80	1345	18	.83	

* B_X = Target Brightness B_H = Horizon Brightness

TABLE IV

TABULAR LISTING OF TRANSMITTANCE AT 10.4 μm RELATIVE TO TRANSMITTANCE AT 1.06 μm OR 0.55 μm

Column A	Column B	Column C	Column D
10.4 > 1.06 or 0.55	Equal	10.4 < 10.4 or 0.55	10.4 <→> 1.06 or 0.55
Fig. 4, A7-(S)	Fig. 8, C-3(S)	Fig. 1, A4(B)	Fig. 10, C6(S)
Fig. 6, B1-(S)	Fig. 12, E-1(S)	Fig. 2, A5(B)	Fig. 15, E5(B)
Fig. 7, B2-(S)	Fig. 13, E-2(S)	Fig. 3, A6(B)	Fig. 16, E6(B)
Fig. 11, D2-(S)	Fig. 14, E-3(S)	Fig. 9, C4(B)	Fig. 5, A8(B)
Fig. 25, TS-34 Kaolin on (CH)/(SP)	Fig. 27, TS-42 Clay/Silt (D)		
Fig. 26, TS-38 (SP)	Fig. 17, TS-2 Clay (D)		
	Fig. 18, TS-6 Clay (D)		
	Fig. 19, TS-19 Clay (MST)		
	Fig. 20, TS-20 Silt (MST)		
	Fig. 21, TS-21 Sand (D)		
	Fig. 22, TS-24 Sand (D)		
	Fig. 23, TS-27 Silt (Wet)		
	Fig. 24, TS-31 Silt (Wet)		

(S) = Surface Event
(B) = Buried Event
(D) = Dry Soil
(MST = Moist Soil

(Sp) = Sand
(Ch) = Clay
TS = Tailored Soils

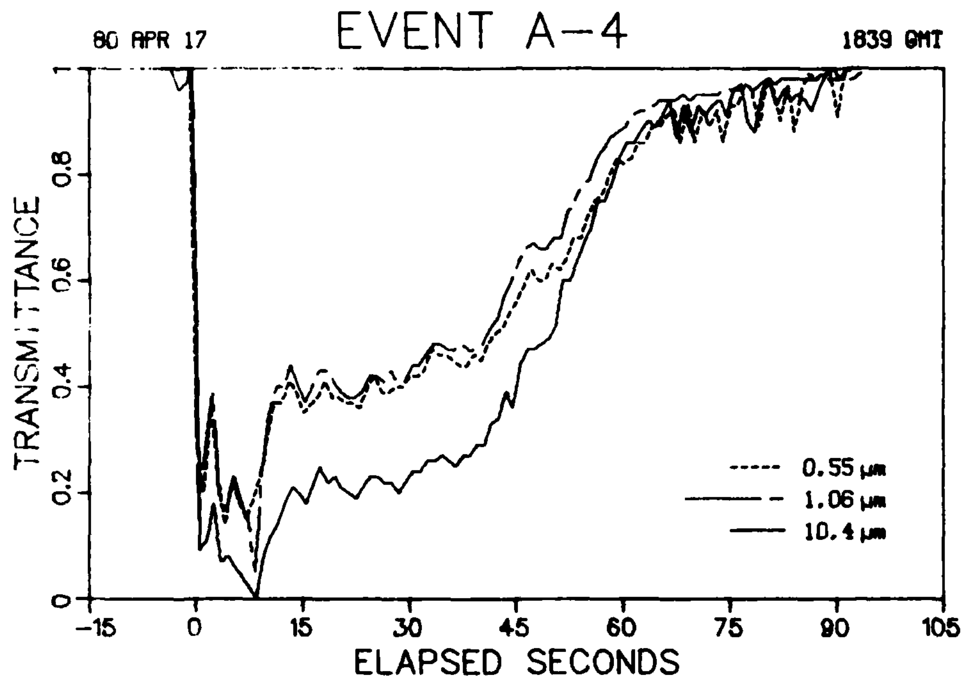

Fig. 1 A4 - 155 STB.

This device was buried in wet natural soil on CL. Wind was calm, transmittance at 10.6 µm was lower than visible or 1.06 µm during entire run of 90 secs.

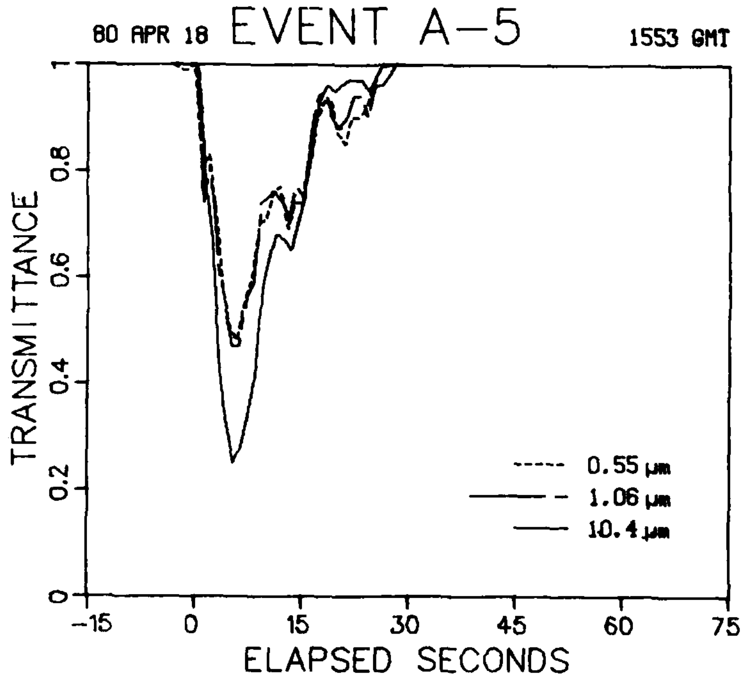

Fig. 2 A5 - 155 STB.

This device was buried in wet natural soil 10 MLCL, wind was 7 kt, Dir 300 (255 to CL), cloud moved rapidly across CL. The dense portion of cloud shows IR having lower transmittance than visible or 1.06 μm

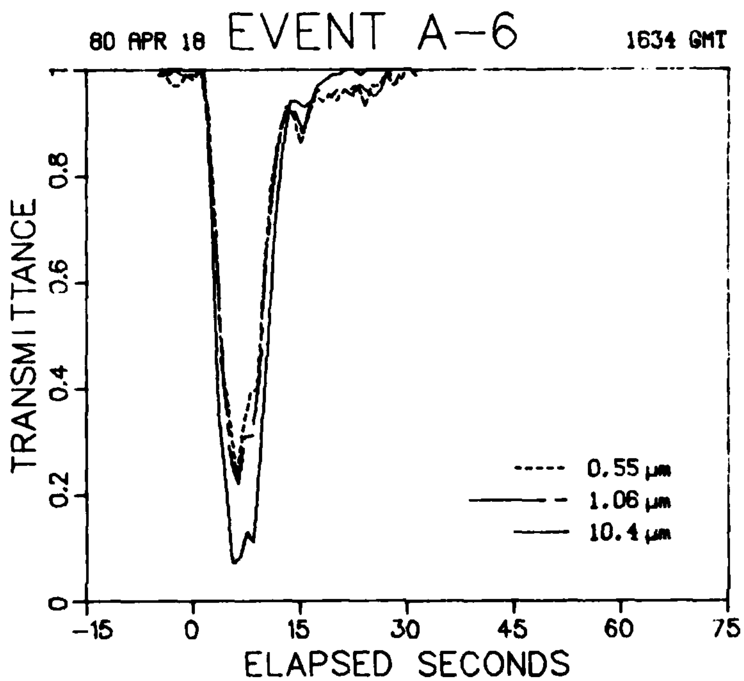

Fig. 3 A6 - 155 STB.

This device was buried in wet natural soil 10 MLCL, wind was 7 kt, Dir 290 (245 to CL), cloud moved rapidly across CL. Dense portion of cloud shows lower IR transmittance than visible or 1.06 µm.

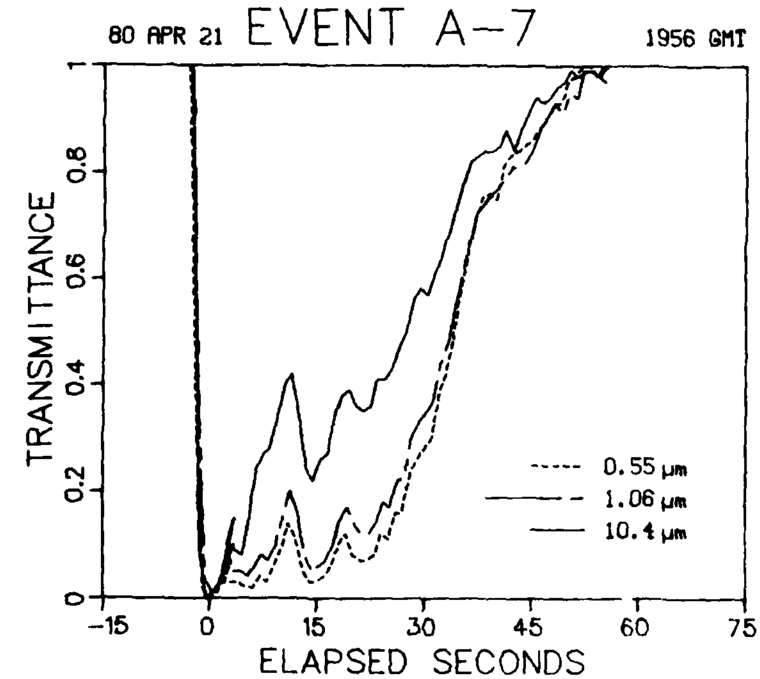

Fig. 4 A7 - 155 SB.

155 surface shot, dry soil, shows higher transmission in IR for the entire run of about 55 secs. Good data wind 4 kt, Dir 270 (225 to CL). Cloud moved across beam W → E.

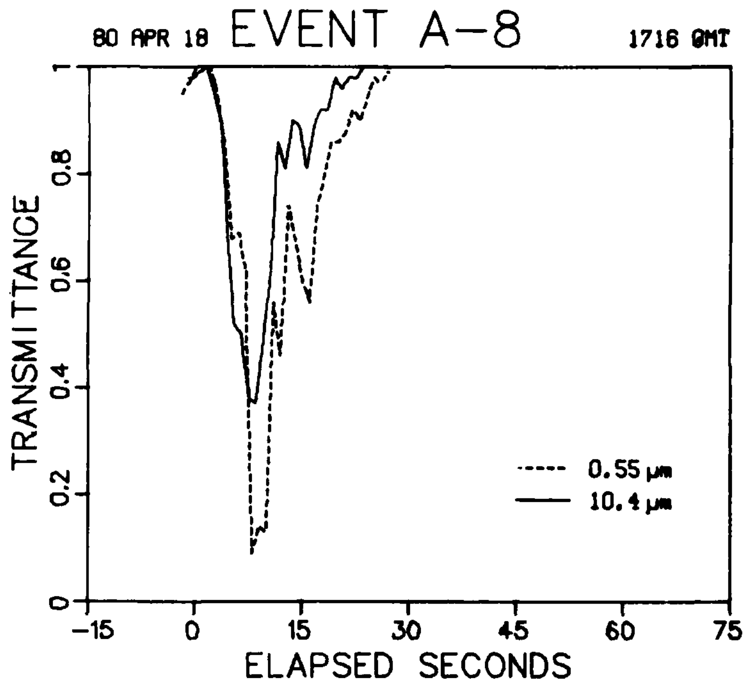

Fig. 5 A8 - 155 SB.

This was a buried charge in wet natural soil. The transmission curves are unusual in that the early data when the cloud sample had a high content of wet soil the 10.4 transmittance is less than visible. Beyond +7 secs where the cloud sample is mostly smoke, the IR is > than visible. Charge 20 M W CL, wind 5 kt, Dir 300 (255 to CL).

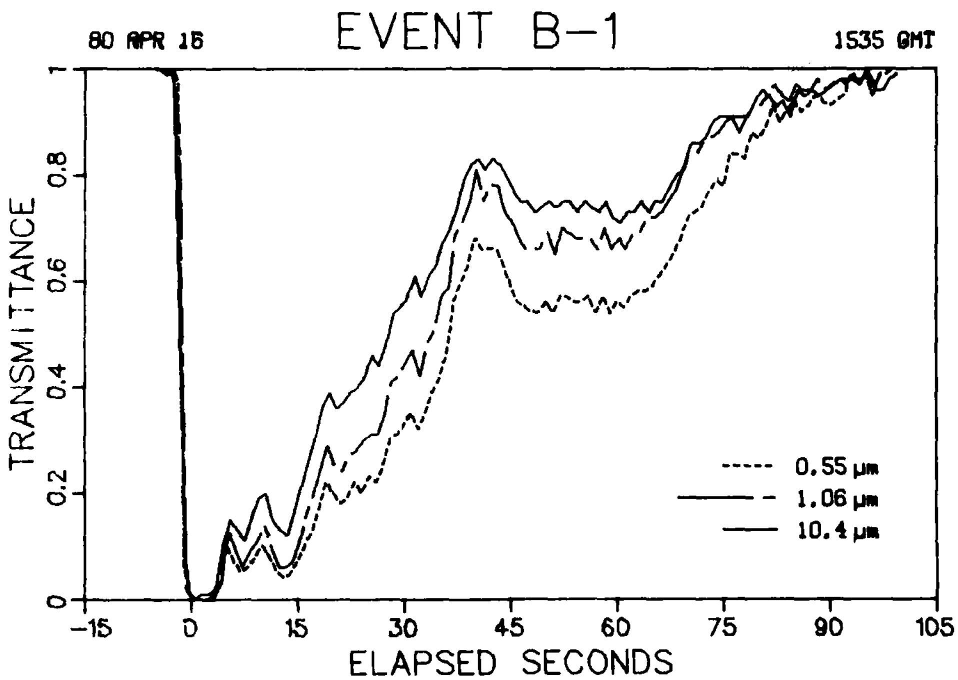

Fig. 6 B1 - 105 ST.

This was a surface charge in dry surface natural soil on the optical axis. Excellent data was obtained for about 100 secs. IR transmission is > than visible for the entire run. Charge on CL, wind 5 kt, Dir 140 (95 to CL).

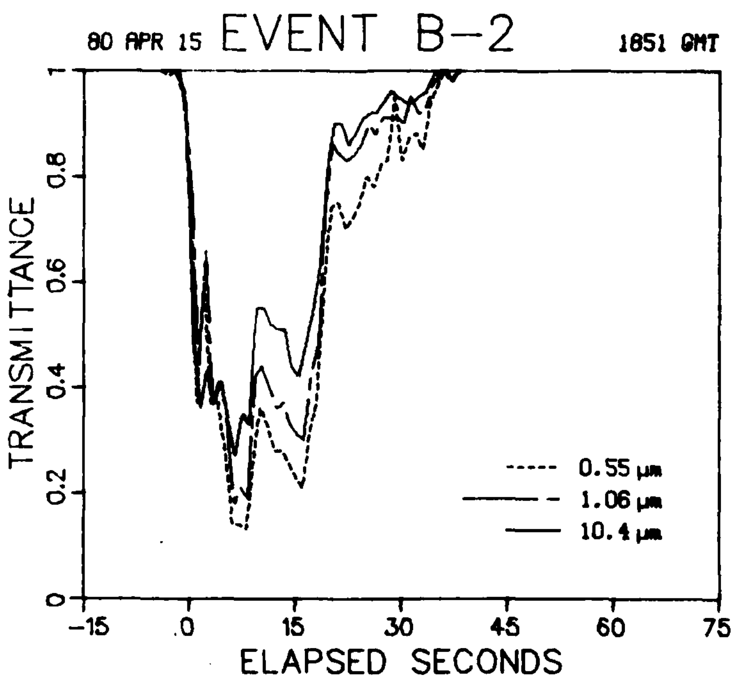

Fig. 7 B2 - 105 ST.

Surface shot, dry soil, cloud blown across beam W → E. IR transmission > visible and 1.06 μm beyond 10 secs wind 4 kt, Dir 290 (245 to CL).

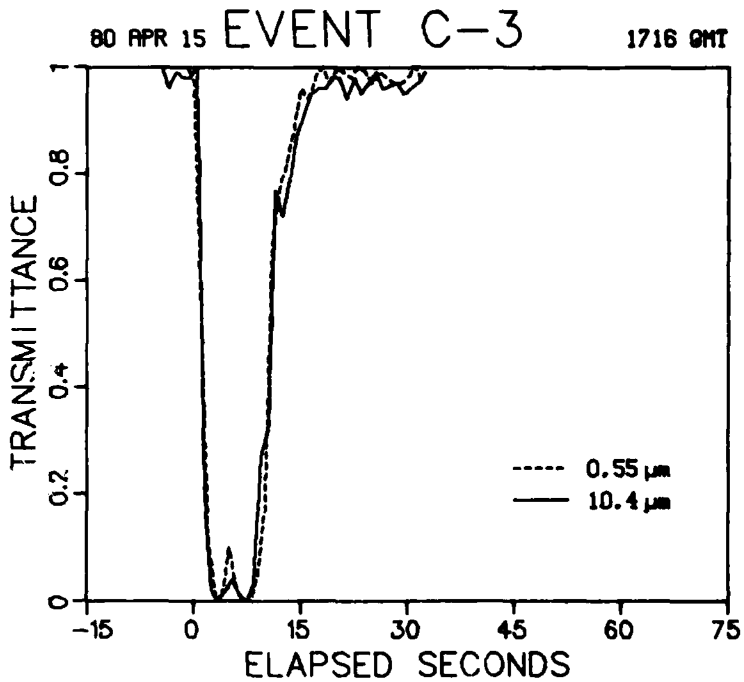

Fig. 8 C3, C4, 26 1/4 lbs ST.

Surface shot, dry soil, IR and visible are equal for short run of about 10 secs. Device 10 MLCL, wind 5 kt, DIR 295 (240 to CL), full cloud blown across beam.

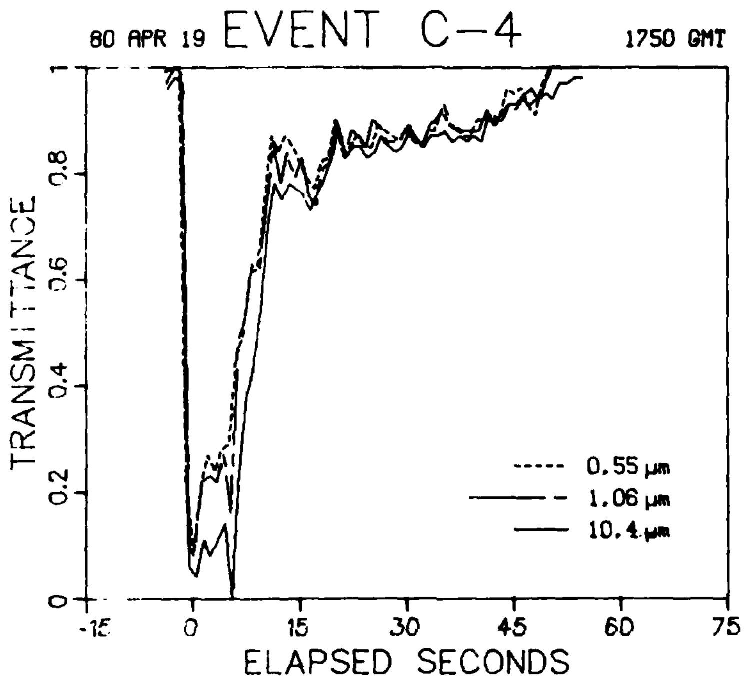

Fig. 9 C4, C4 15 lbs, STB.

Buried shot, moist soil, IR transmission < visible or 1.06 μm for most of run of 50 secs. This effect is greater in early time for about 5 secs when visible transmission is about 20%, wind 3 kt Dir 20, (335 to CL), charge on CL, cloud blown toward receiver.

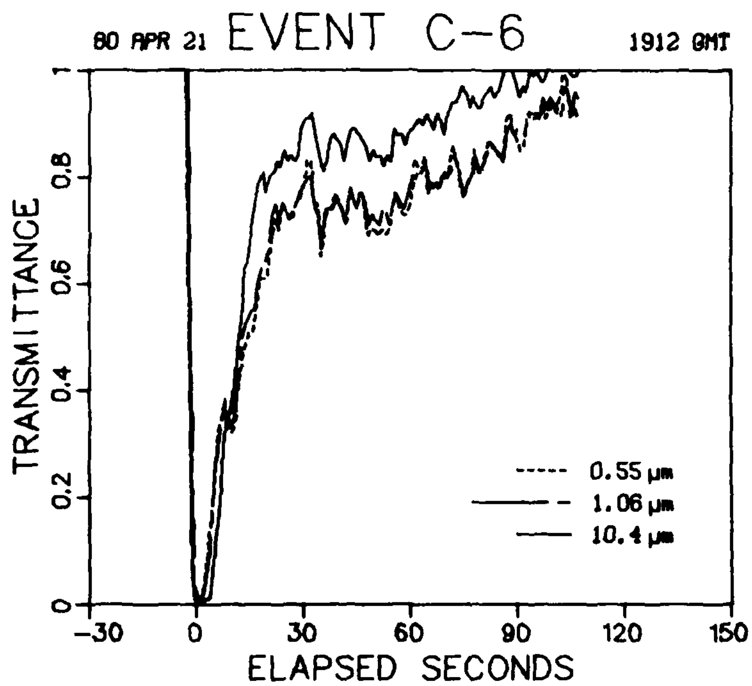

Fig. 10 C6, C4 SB.

This was an early morning surface shot in calm conditions in natural dry surface soil. Transmittances at 0.55 and 1.06 µm are similar as shown in the figure. Data was obtained for about 110 secs. Charge on CL, wind 2 kt Dir 340 (295 to CL).

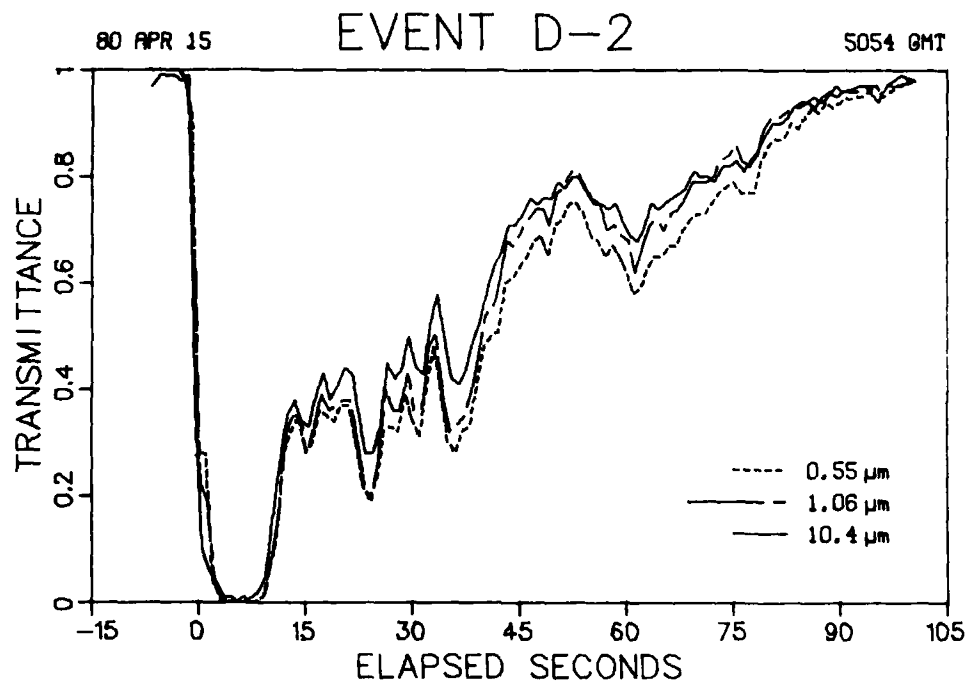

Fig. 11 D2,122 ST.

This was a surface shot in calm conditions in natural dry surface soil. Data was obtained for about 110 secs. This is typical data for dry soil and smoke cloud where IR transmittance is > than visible and 1.06 μm. Charge 10 M W CL, wind calm.

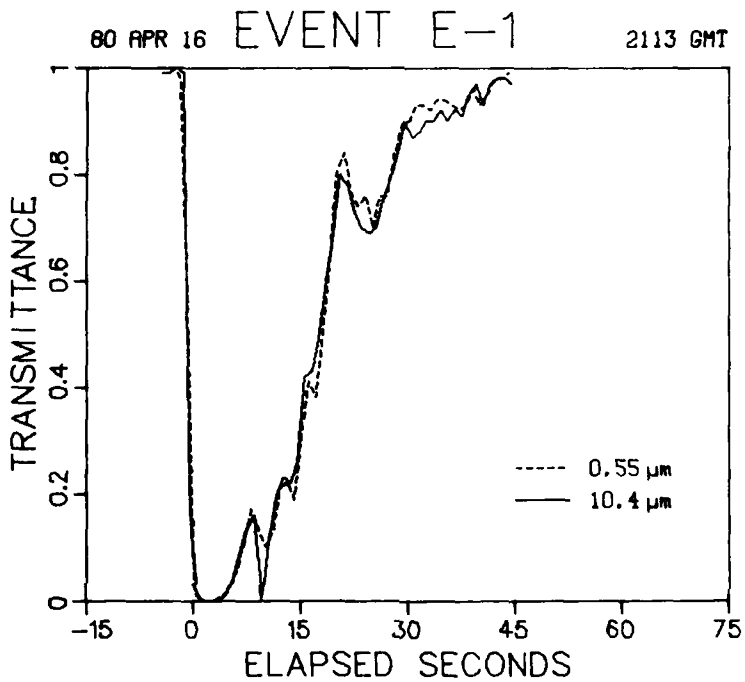

Fig. 12 E1, 152 ST.

Surface shot, dry soil, all wavelengths have equal transmission in range 0 to 100%. Wind 4 kt, Dir 160 (115 to CL), charge on CL blown away from receiver.

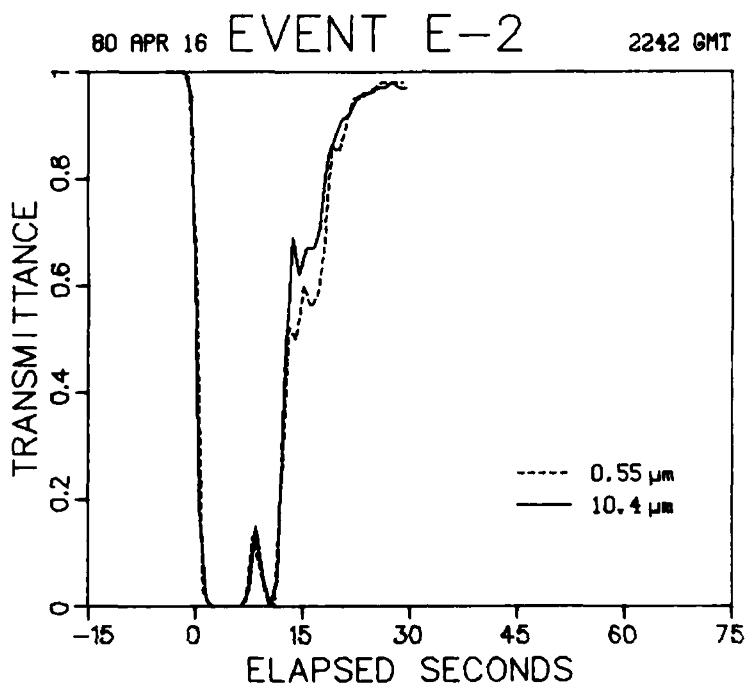

Fig. 13

Surface shot, dry soil, visible and IR transmittances are equal to 15 secs. Visible is lower from this point to end of run. Charge was 10 MECL, wind 2 kt, Dir 180, (135 to CL).

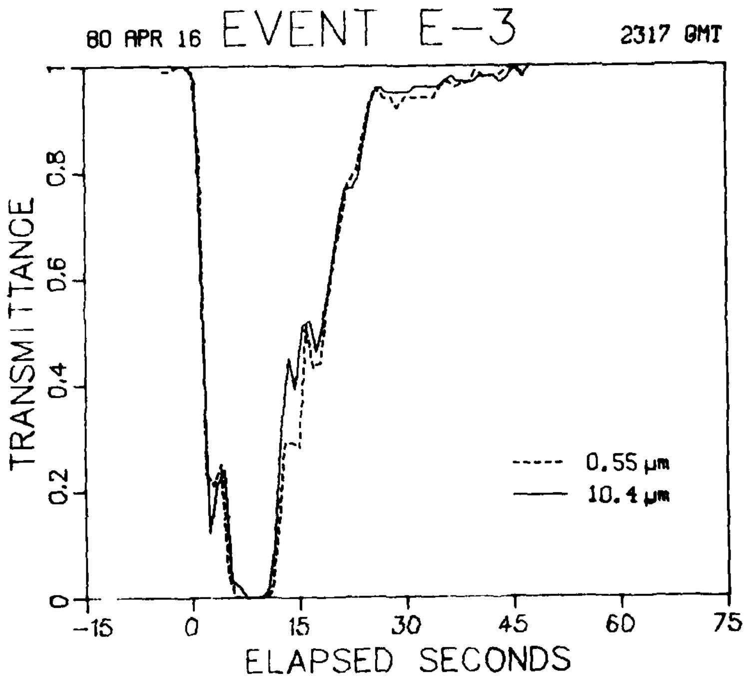

Fig. 14 E3, 152 ST.

Surface shot, dry soil. IR transmittance several percentage points higher than visible for entire run of 50 secs. Charge 20 MECL, wind 5 kt, Dir 180 (135 to CL).

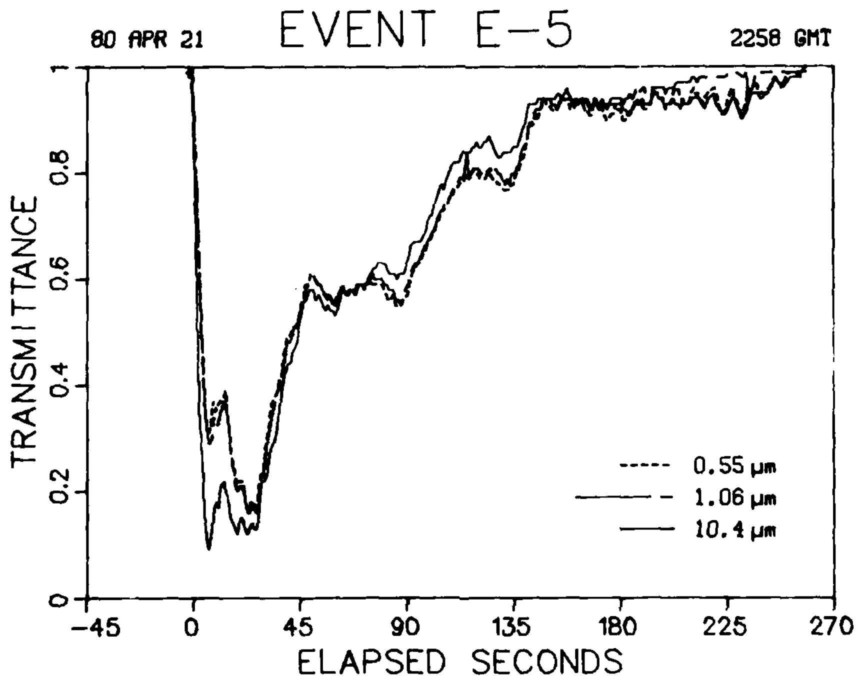

Fig. 15 E5 155 STB.

This was a buried shot in calm conditions in natural dry surface soil. Data was obtained for about 250 secs. IR transmittance was lower than visible or 1.06 µm for about 65 secs. Beyond this point the cloud sample ·onsisted of smoke and dry dust so that IR transmittance was > than visible or 1.06 µm. Charge 10 M W CL, wind calm.

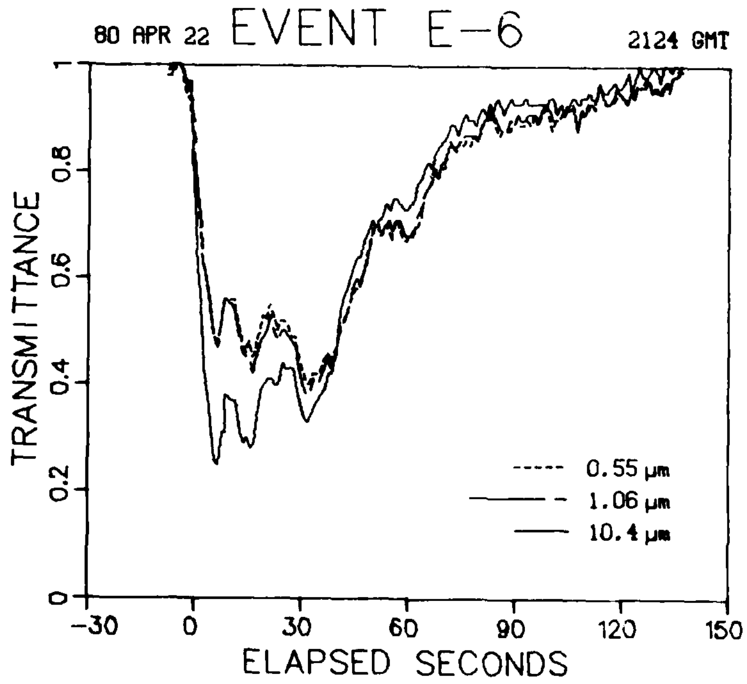

Fig. 16 E6, 152 STB.

Buried shot, dry soil, IR transmittance lower than visible to +40 secs, higher to end of run at +135 secs. Charge 10 MWCL, wind 5 kt, Dir 240 (195 to CL).

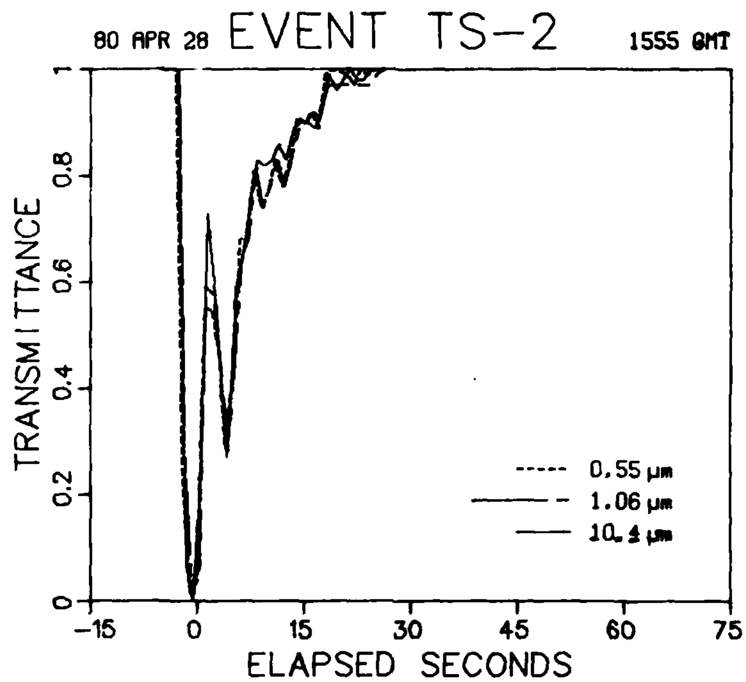

Fig. 17 TS-2 - Dry Clay 5 lbs.

Prepared soil dry clay transmittances about equal at all wavelengths throughout the run of 20 secs. Charge on CL, wind 7 kt, Dir 310 (265 to CL).

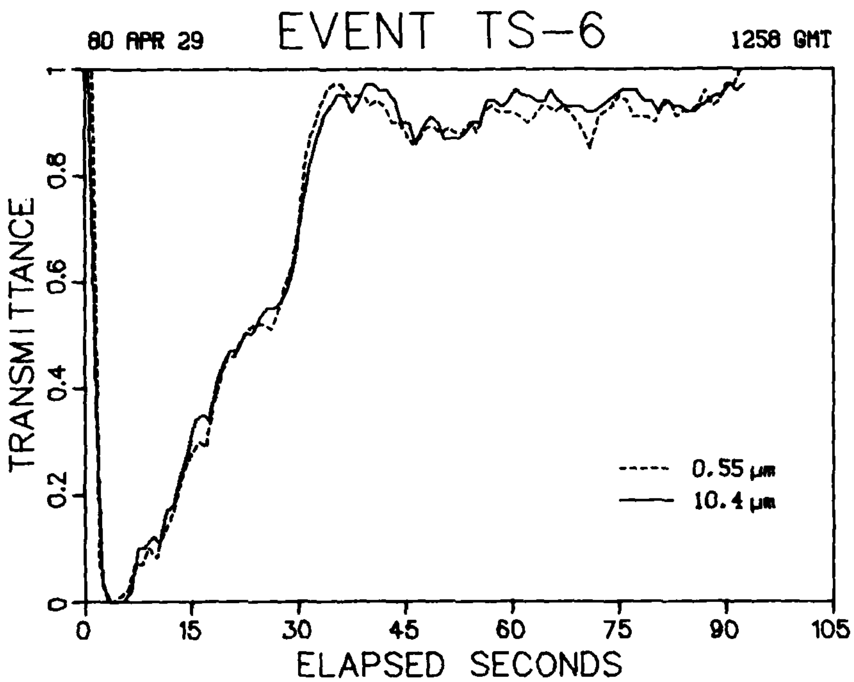

Fig. 18 TS-6 - Moist Clay, 10 lbs.

Prepared soil dry clay transmittances equal at all wavelenghts through cloud for +35 secs and through residual to about +90 secs. Charge on CL, wind calm.

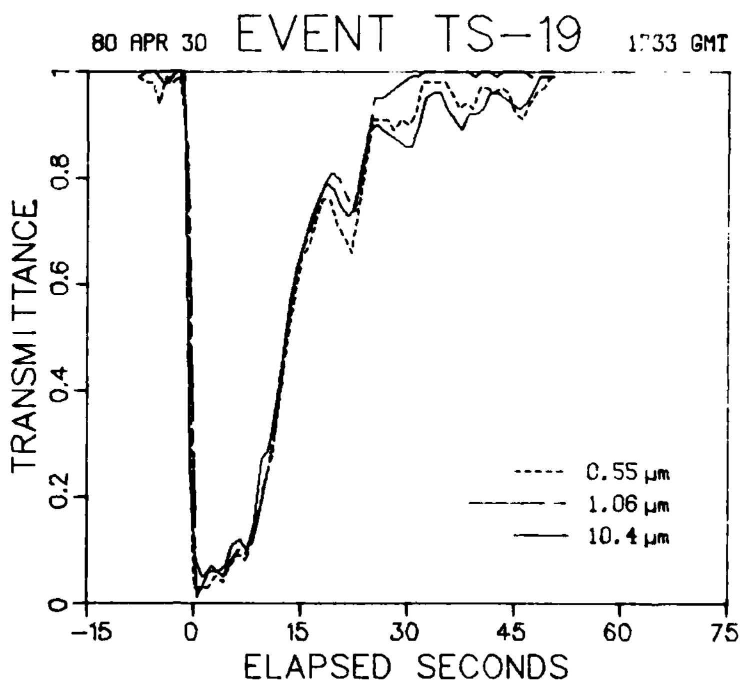

Fig. 19 <u>TS-19 - Moist Clay, 10 lbs.</u>

Prepared soil moist clay transmittance equal at all wavelength to about 15 secs, 10.6 μm slightly greater in residual to about +50 secs. Charge on CL, wind 7 kt Dir 180 (135 to CL).

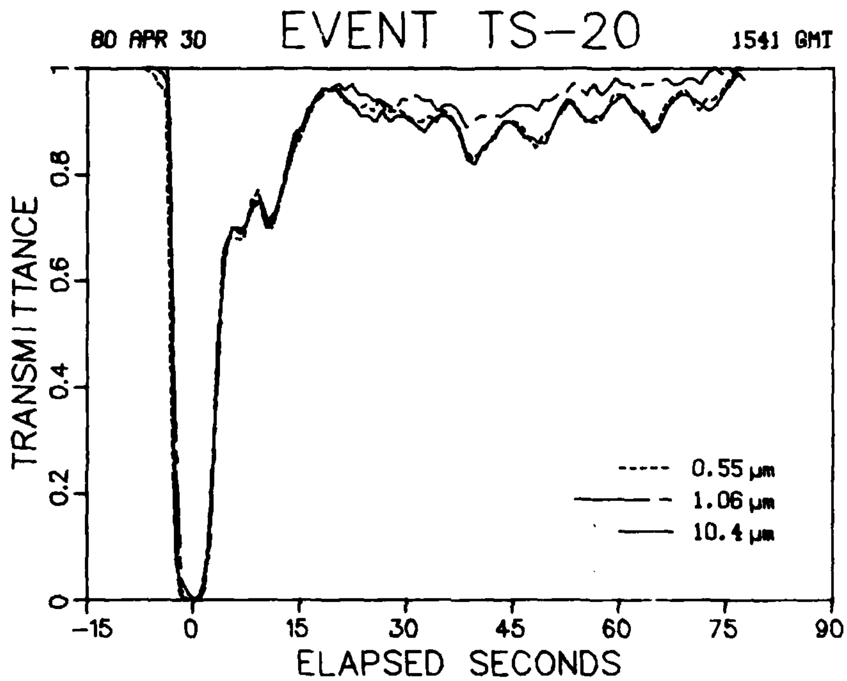

Fig. 20 TS-20 - Moist Slit, 10 lbs.

Prepared soil, moist silt. Fair data transmittance equal at all wavelengths for about +20 secs, 10.6 m slightly greater in residual cloud to about +75 secs. Charge on CL wind 4 kt, Dir 190 (145 to CL).

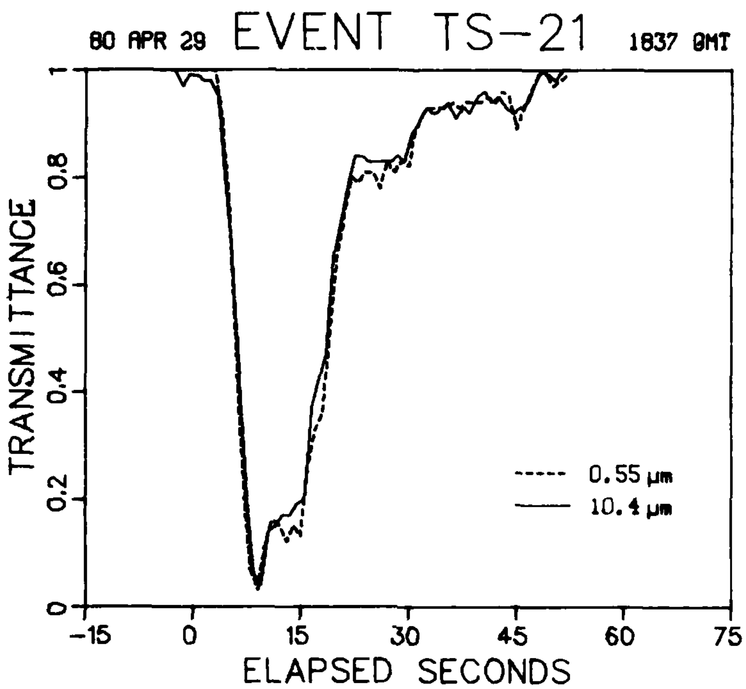

Fig. 21 TS-21 - Dry Sand 5 lbs.

This shot consisted of 5 lbs of explosives in a prepared soil of dry dans. Data shows similar transmittances for visible and IR. Charge 20 MW of CL, wind 270 (225 to CL) at 5 kt.

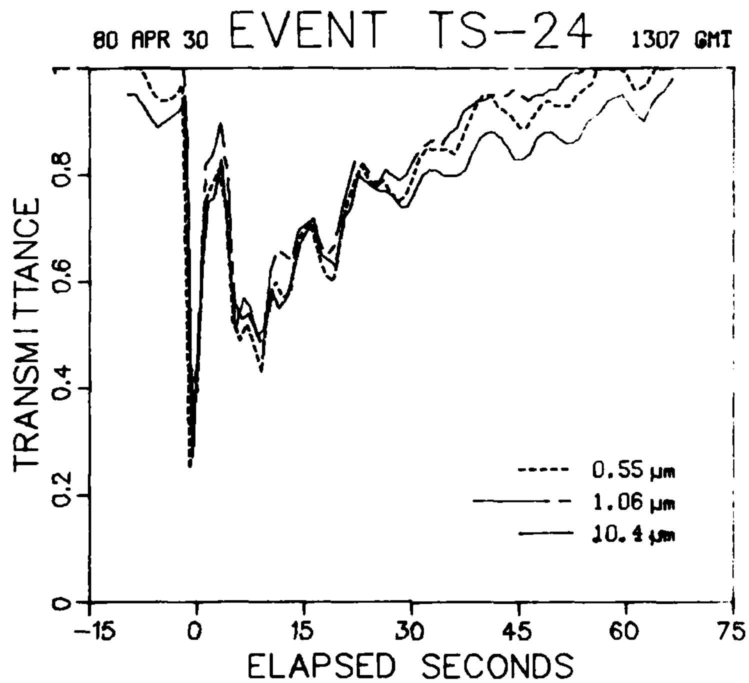

Fig. 22 TS-24 - Dry Sand, 10 lbs Charge.

Prepared soil, dry sand, calm, beam passed through hole in cloud, good data, 10.6 µm slow in reestablishing 100% level. Charge MCL, wind calm.

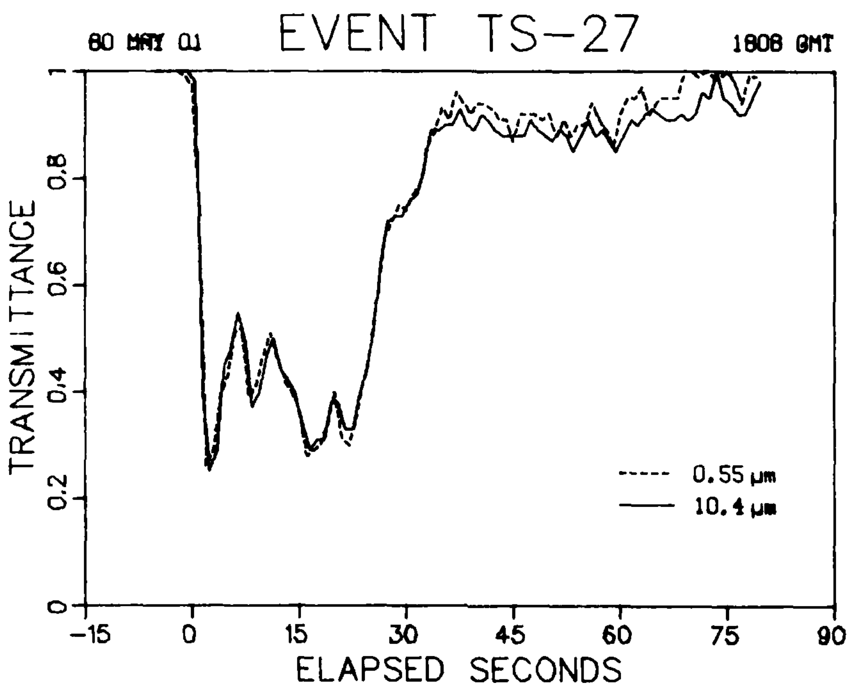

Fig. 23 <u>TS-27 - Wet Silt 5 lbs.</u>

This shot consisted of 5 lbs of explosive in a prepared soil of wet silt. Data shown similar transmittance for visible and IR for about + 35 secs. From this point to about + 80 secs visible transmittances are a few percentage points greater than IR. Charge 10 M E of C1, wind 4 kt, Dir 160 (115 to CL).

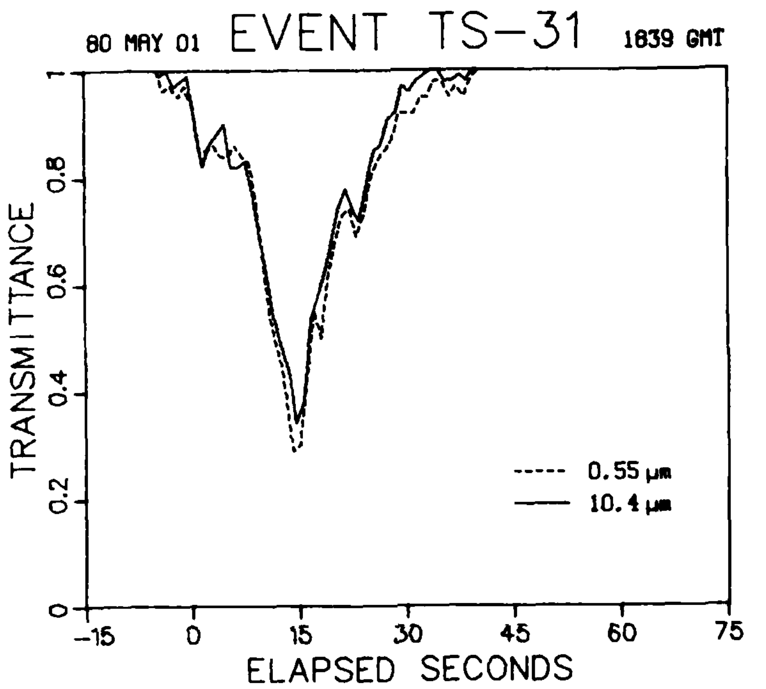

Fig. 24 TS-31 - Wet Silt, 10 lbs. Charge.

Prepared soil, wet silt. Wind 4 kt, Dir 200 (155 to CL). Main cloud drifted above beam, good data for lower residual cloud. All wavelengths show equal transmittance charge 20 M W of CL, wind 4 kt, Dir 200 (155 to CL).

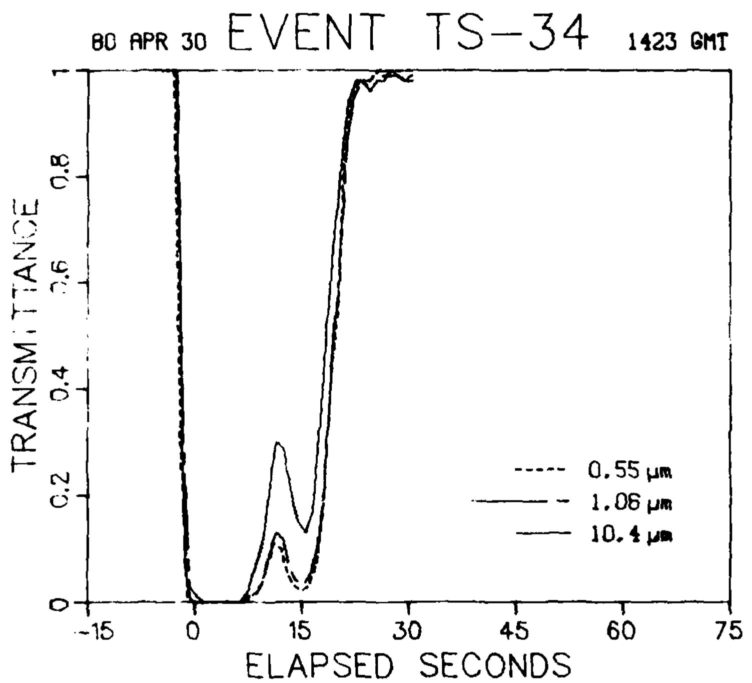

Fig. 25 TS-34 - Kaolin on Clay, Dry Sand, 15 lbs Charge.

Prepared dry soil mixture of Kaolin on clay and sand. 3 kt, Dir 200. 25 secs of good data, 10.6 m greater than visible on 1.06 μm in dry soil mixture. Charge on CL, wind 2 kt, Dir 200 (155 to CL).

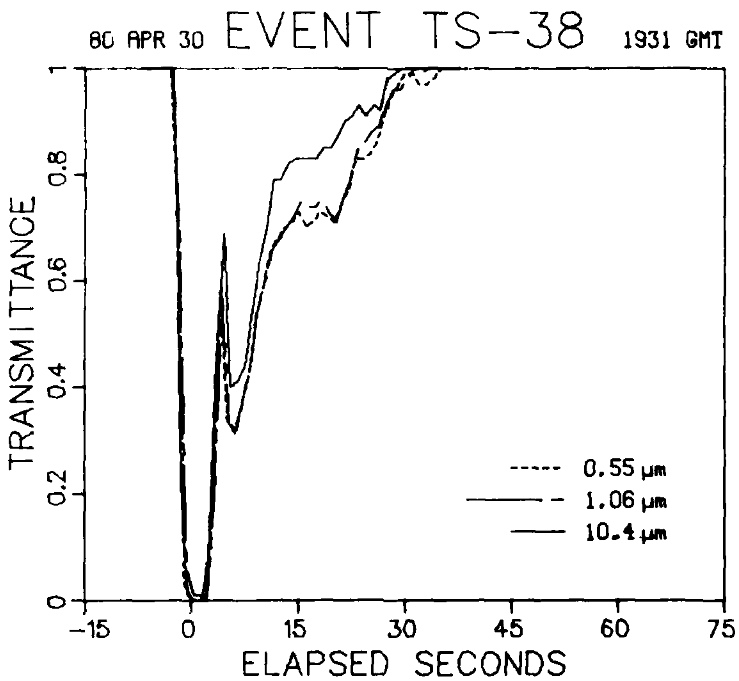

Fig. 26 TS-38 - Moist Sand, 10 lbs Charge.

Prepared soil of moist sand. 5 kt wind at 180 (135 to CL) Quick pass of main cloud, lower cloud drifted into beam for 35 secs where 10.6 μm shows a few percent higher transmittance than visible or 1.06 μm.

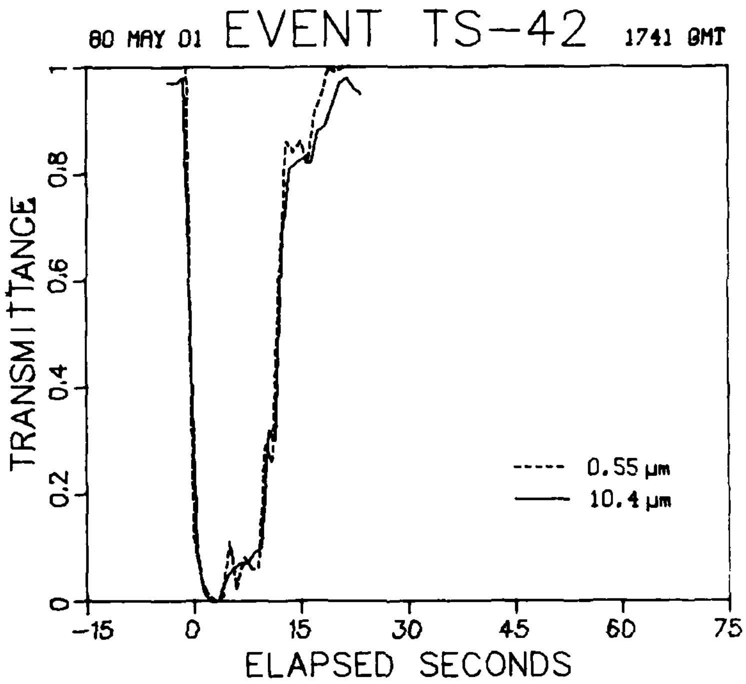

Fig. 27 TS-42 - Dry Sand/Slit 5 lbs.

This shot consisted of 5 lbs explosive in a prepared soil of dry sand/slit. For most of the time the IR and visible transmittances are equal. Charge on CL, wind 4 kt, Dir 180 (135 to CL).

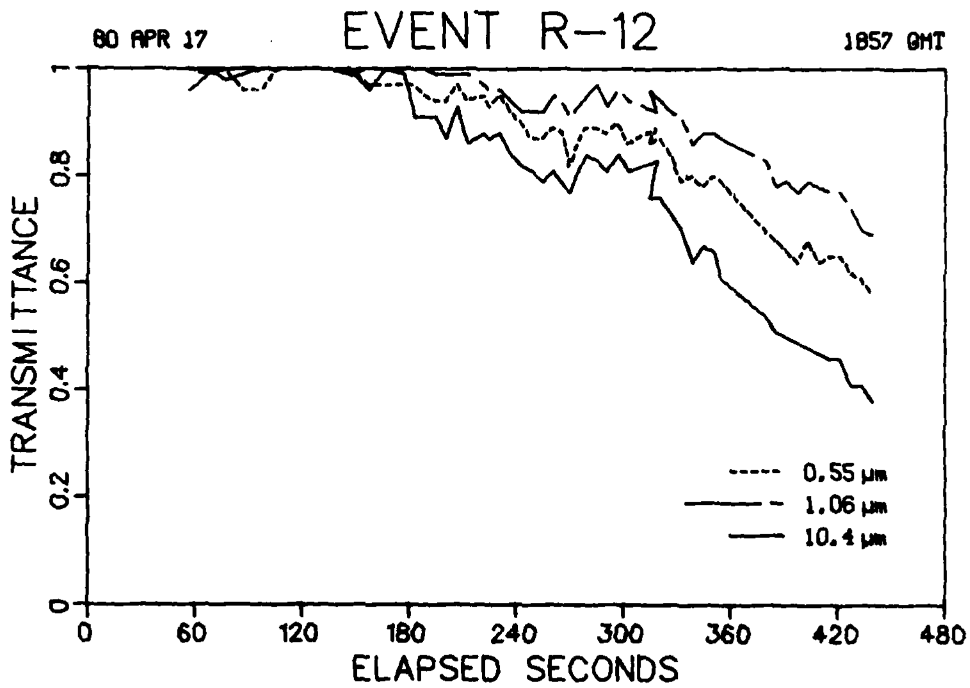

Fig. 28 Event R-12.

This figure shows transmittances through rain for about 6 minutes beginning at 1858 on 4/17. Observations were interrupted at + 430 secs because of equipment failure. This data shows IR at 10.4 µm has lower transmittance than either visible or 1.06 µm.

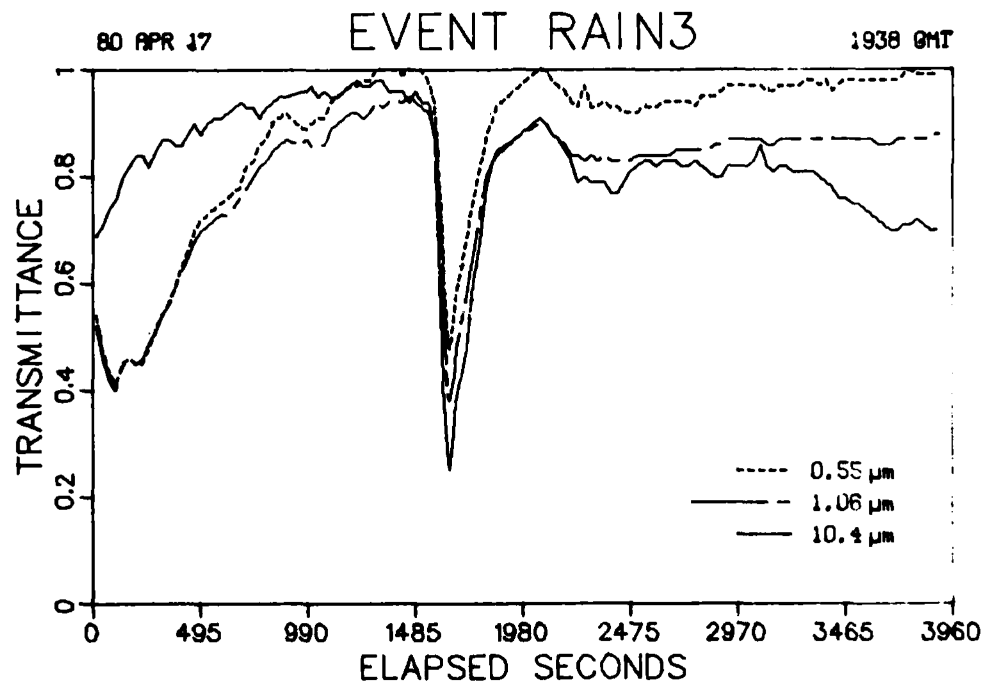

Fig. 29 Event Rain 3.

This figure shows rain transmission data after equipment repair on 4/17 beginning at 1938 for about 1 hour. The figure indicates a brisk shower at about + 1600 secs where 10.37 µ transmission has a minimum value of 25% or about 1/2 the corresponding visible value. There is an unusual occurrence here in that IR is greater before the shower and generally less after the shower has passed through.

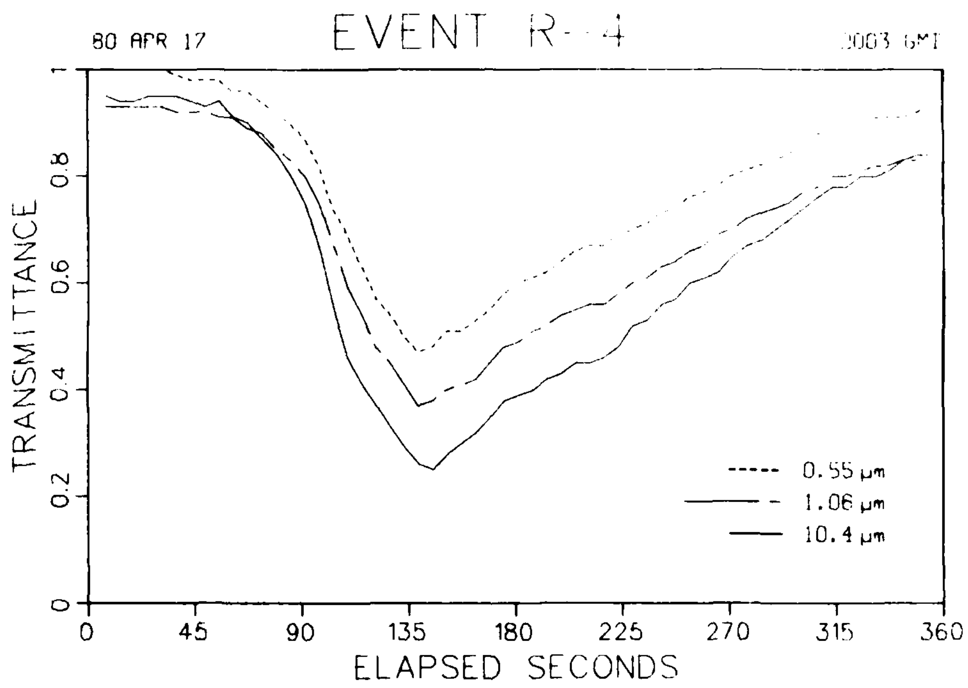

Fig. 30 <u>Event R-4.</u>

This figure shows a higher time resolution of transmittance during the shower in Event Rain 3.

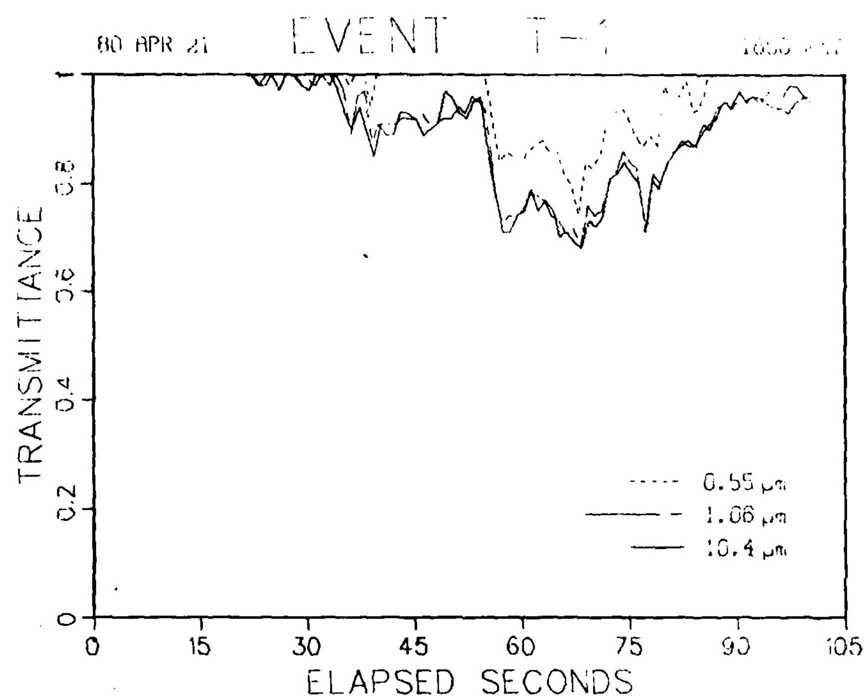

Fig. 31 **Event T-1.**

Transmittance of a thin vehicular dust cloud.

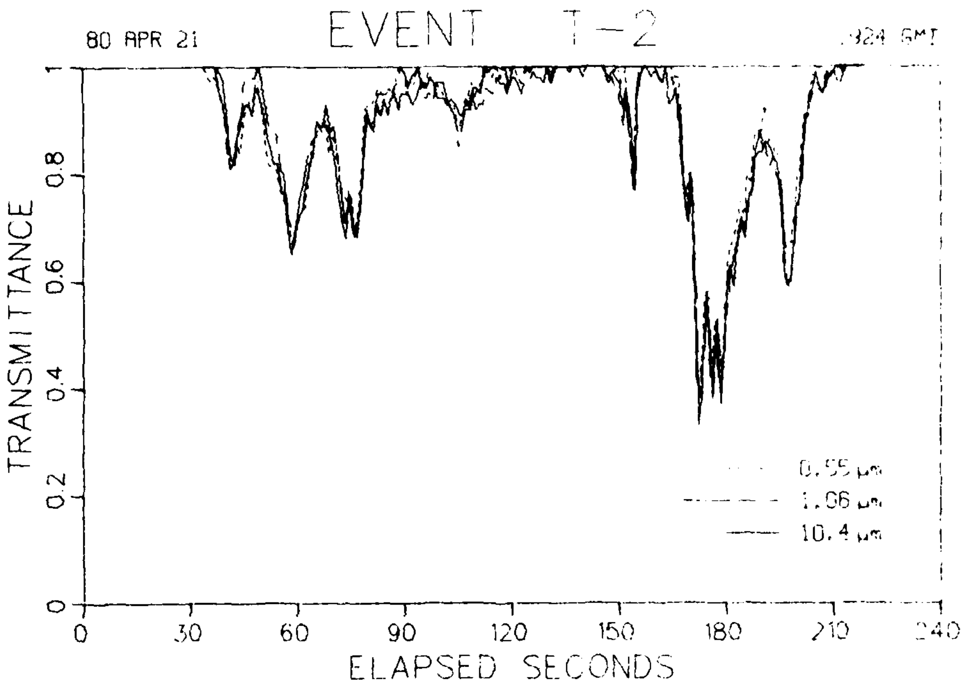

Fig. 32 Event T-2.

Transmittance of a vehicular dust cloud. Transmittance is equal for all wavelengths in the range down to 40% transmittance.

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